THE INSIDE PROJECT ON INHERENT SHE IN PROCESS DEVELOPMENT AND DESIGN - THE TOOLKIT AND ITS APPLICATION

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The paper reports progress on an industry / CEC co-sponsored project INSIDE, (Inherent Safety In DEsign) on Inherent Safety, Health and Environmental protection in the development and design of chemical processes. The hurdles to the use of Inherent SHE are summarised. The paper outlines a toolkit which has been developed to assist the application of Inherent SHE, which covers all stages of process development from the selection of the process route through to detailed design.

Keywords: Inherent SHE, Safety, Health, Environmental Protection, Process route selection, Design.

1. INTRODUCTION

The concept of 'Inherently Safer' plants was first introduced by Trevor Kletz in 1978 (almost 20 years ago). Since then the topic has been the subject of a steady stream of papers with clear signs that interest in the topic is increasing.

- The AIChemE devoted its October 1996 seminar in Orlando to the topic.
- Feature article in the 'Chemical Engineer'
- The issue of a new training package by the IChemE
- Recent meeting of the Safety & Loss Prevention Interest Group of the IChemE

There is also a general recognition within the process industries that safety, health and environmental issues will remain high on the agenda. In addition, if the industry is to compete with low-cost producers elsewhere in the world, European industry will need to develop new processes capable of providing it with a competitive edge.

This paper will report on progress by the industry/CEC co-sponsored project, INSIDE (INherent Safety In DEsign) which is taking a European wide view of the topic. At the last Manchester seminar (Hazards XII) a paper was presented which provided an overview of the status of inherent SHE at the start of the project, and described some of the hurdles to its introduction and use.(Reference 1)

This Paper will describe the work carried-out by the project team over the last two years, concentrating on the development and trials of a 'Toolkit'.

2. APPLICATION OF INHERENT SHE

The first phase of the INSIDE project consisted of reviews of :

- Literature
- Lessons from quantified risk assessments
- Lessons from accident investigations
- Review of Regulations and Standards
- Industry Interviews

All of these have already been reported. (Reference 1)

The most interesting results, since they reflect the factors which help or hinder the application of Inherent SHE, come from the 'Industry Interviews'. Over 20 companies were interviewed, representing a broad spectrum of the process and chemical industry, including production companies from the hydrocarbon, pharmaceuticals, bulk chemicals, fine chemicals, agrochemicals, plastics, fibres and polymers sectors. Large, medium and small companies were represented. A number of major design and engineering contractors and a process licenser were also included.

Although there were some differences in the status and views of inherent SHE between the different types of organisation, the main findings were common to all sectors of industry and types of organisation.

Addressing SHE : Few organisations had any formal SHE specialist involvement at the process development stage, relying on the skills of the development team themselves to be aware of the SHE issues. By the design stage, around 33% of the companies had brought in a SHE specialist, but for many, the HAZOP of the detailed design was the first and only structured safety review. By that time it is frequently too late to make significant changes.

Role of Procedures : Most companies had some form of development and design procedures covering SHE aspects of a project. However, only 25% of these procedures mentioned inherent SHE or any of its underlying principles. Inventory reduction and substitution were the 2 most commonly mentioned. Few of the procedures asked for alternative options to be considered at the development stage.

Awareness : Awareness of inherent SHE principles was mainly confined to SHE specialist, with only 15% of development or design departments having any significant awareness. This reflects the level of training, with only around 10% of organisations including inherent SHE in their training programmes.

Benefits : Despite this lack of awareness, many of those interviewed thought that inherent SHE approaches would offer a competitive advantage and be worthwhile following. About 33% thought it could help reduce plant costs, and 70% quoted other benefits such as : simpler operation, more reliable plant, improved public image and SHE performance. It was recognised that these benefits would best be achieved by considering inherent SHE at the earliest stages of any project.

Key Pressure on Development and Design : Companies were asked what pressures they felt had most influence on the way they approach the development and design activities and the way SHE is addressed within this. The most common pressures were the need to drive down costs. Companies are also under increasing pressure to get products to the market place ahead of the competition. This is reducing the programmes for development and design, increasing the need for parallel working and giving less time to think about alternatives. The case for inherent SHE therefore needs to be able to demonstrate that time and effort spent at the early stages of the project, can produce greater savings later on by reducing the need for costly changes or remedial action late in design.

Hurdles to Inherent SHE : The main hurdles to adopting inherent SHE were considered to be the lack of awareness, and conservatism in the design and general management (See table 1). Prescriptive regulatory requirements and cost and time pressures were also sited as problems.

Table 1 - Main Hurdles to Adopting Inherent SHE

HURDLE	%
Lack of Awareness	30
Conversantism in Design/Management	20
Cost/Time Pressures on Project	15
Need to meet Legislative Requirements	15
Others	20

3. MEETING THE NEEDS

Although some of the hurdles to the introduction of inherent SHE noted above will be specific to an organisation or even a particular project (for example, contractor client relationship) the two generally expressed needs were for:

- Improved training
- A systematic method

3.1 Training

In 1996 the 'International Process Safety Group', in association with the IChemE, introduced a training package on inherent safety which can be used 'in house' by companies to meet the needs both of training and of awareness.

3.2 Systematic Method

The second phase of the INSIDE project has concentrated on the development of a systematic method or 'toolkit' which is described below.

4. SCOPE OF THE TOOLKIT

The review of literature had revealed that much of the earlier thinking had concentrated on 'inherent safety' alone. Surprisingly, in light of the current emphasis on environmental issues, few papers were found proposing an inherent approach to the reduction of environmental impact. Most environment papers tended to focus on specific measures such as waste minimisation and effluent treatment rather than presenting an overall framework to minimise environmental impact. The project team took the view from the beginning that an integrated approach, considering safety, health and environmental issues as part of one co-ordinated process, would be of greatest value to industry, minimising potential conflicts and avoiding time wasting duplication of effort.

The survey also showed that a flexible approach to inherent SHE was required. The projects undertaken by companies can range in scope from the production of an entirely new material, where several process routes may be available, to the extension or debottlenecking of an existing process.

Decision Points An analysis was undertaken to identify the key decision stages involved in the selection of a process and the design of a plant. Such an approach is outlined by Kletz (1991) ,a summary of this is shown in Table 2. It was found that many of the key decisions are taken at a very early stage in the development of the process, even as far back as the specification of the product. In terms of inherent SHE, the main decision point appeared to be:

- preparing the product specification
- selecting the chemistry/synthesis route to be used
- developing the chemical flowsheet (feeds, reaction steps, conditions etc.)
- developing the process conceptual design (process flowsheet, process diagram and mass/heat balances stage and early plant layout)
- incorporating inherent SHE/friendly aspects in detailed design

5. THE TOOLKIT

As noted above, projects come in many forms, from entirely novel processes through to uprating of existing plants. Obviously, both the opportunities to apply inherent SHE and the potential gains are different in each case. To cater for this, the toolkit has been designed as a number of modules capable of being used at various stages of the project. These are shown in figures 1, 2, 3, and 4 with the tools being labelled A to T. It is not our expectation that any one project will use all of the tools, in most cases only a small selection is likely to be applied. In fact some of the tools overlap. This is deliberate. Inherent SHE is not a formal process, such as HAZOP or the design of a pressure relief system.

Three distinct types of activity or processes are involved at each stage of the project, these being:

- Hazard identification- which aspects of the process are likely to give rise to concern.
- Option generation - Are there alternative chemical or process routes which could be used.
- Option evaluation - Which of the options represents the best inherent SHE.

Table 2 - The Steps To Plant Design

Decision	Key Questions/Decisions	Information Used
Initial Specification	What Product What Throughput	*Market Research* *R&D New product ideas*
Process Synthesis Route	How to make the product What route What reactions, materials, starting points	*R&D Chemists research* *Known synthesis routes and techniques*
Chemical Flowsheet	Basic Unit Operation Selection, with Flowrates Conversion Factors, Temperatures, Pressures, Solvents and catalyst selection	*Process synthesis route* *Lab and pilot scale trials* *Knowledge of existing processes*
Process Flowsheet	Batch vs. Continuous operation Detailed Unit Operation selection Control/Operation philosophy	*Information above plus process engineering design principles and experience*
Process Conceptual Design	Equipment selection and sizing Inventory of process Single vs. Multiple Trains Utility requirements Overdesign/flexibility Recycles and Buffer capacities Instrumentation and Control Location/Siting of plant Preliminary plant layout Materials of construction	*As above plus equipment suppliers* *data, raw materials data,* *Company design procedures and requirements*
Process Detailed Design	Detailed specification based on concept design Minimise number of possible leak paths Make plant 'friendly' to control, operate and maintain. Avoid/simplify hazardous activities such as sampling, loading/unloading	*Process conceptual design and codes/standards and procedures.* *Experience on past projects/designs*

5.1 Hazard Identification

Most companies have established procedures for hazard identification. The framework proposed links into these, include the preparation of hazardous properties data sheets, reviews of past experience, laboratory chemical and thermal assessment, HAZOPs and other guideword led studies. The data collected may also be used to assess if the alternatives generated are safer or whether they could make matters worse.

5.2 Option Generation

An important part of the toolkit is an option generator which prompts chemists and engineers to identify alternatives (materials, routes, process conditions, unit operations, equipment depending on the stage) which can then be evaluated. The option generation stages provide a guideword based analysis tools that:

- challenge the basis of the initial proposal to clarify the fundamental purpose/functionality of any step or item and prompt the identification of other ways to achieve this purpose. This approach is intended to stop the natural inclination to adopt previous or 'accepted' solutions without thinking it through or seeking any alternatives.

- Prompt the consideration of deviations from the initial proposal to identify alternative options.

Examples of these guideword/functional prompts are presented in tables 3 and 4. Here, the proposed process flowsheet would be broken down to identify the fundamental unit operations and conditions. The guidewords for the relevant parameters in Table 3, would be used to prompt the consideration of deviations from the initial proposal. Once the basic unit operations have been evaluated in this way, the next stage of assessment would take place using the Guidewords in Table 4 to consider the various alternative means of achieving that function. Similar guideword structures have been developed for process route selection.

As an example take the case where the step being considered is chemical reaction. The guidewords from table 3 would prompt consideration of firstly eliminating or avoiding the reaction step, carrying it out elsewhere etc. Further guidewords would challenge the processing method , equipment , timing , physical and chemical conditions etc. If the reaction involved mixing the keywords in table 4 would be used to prompt consideration of alternative methods of mixing.

The structure of the framework will allow other tools and examples to be used if the assessment stalls. These would include formal techniques to help identify the key functions or purpose of any item or step (functional analysis, critical examination) where these are complex or not obvious and relevant examples of inherent SHE which might be tried or which may promote another line of thinking.

Table 3 - Process Flowsheet Assessment Parameters/Guidewords

Parameter	*Guideword*	Deviation
Process Stage **(Apply to unit operation or process feed/junction)**	*Avoid Change*	Eliminate/Avoid Elsewhere Combine Split Segregate
Processing Method	*Change*	Batch/Continuous Processing Method (see functionality assessment keywords)
Equipment	*Change*	Size Geometry Type
Timing	*Change*	Sequence Duration Timing Feed Profile
Physical Conditions	*Change*	Pressure Temperature State (solid, liquid, vapour) Level
Chemical Conditions	*Change*	Material Concentration Composition Catalyst Solvent Mixing

Table 4 - Example of Process Flowsheet Functionality Keywords

FUNCTION	KEYWORD
MIX	*Dissolve* *agitate* *Blend* *Inject* *Fluidise* *In-line*
SEPARATE	*Settle* *Extract* *Vaporise* *Condense* *Precipitate* *Enhanced g* *Pressure Swing* *Reverse Osmosis* *Filter*
REACTION	In-line Pot Tube *In existing equipment* High intensity
TRANSFER	Pump Eject Siphon Gravity Container *Convey* Compression

5.3 Screening of Options

It will be impracticable to develop all of the options and screening processes are required to identify those options worth more detailed consideration. As with other elements of the toolkit the degree of detail involved in the screening needs to reflect the stage of project / process development.

At the earliest stages only limited information is likely to be available. To meet this requirement simple screening criteria have been developed based solely on the properties of the chemicals involved. This type of screening could be carried-out by one person with access to the relevant data .

At later stages of the project , where more information is available, the decisions are likely to be more complex and the screening will need to take account of many additional factors. To assist at this stage a form of multi-attrribute analysis has been developed. This uses a semi-quantitative approach to give a ranking to each of the following aspects:

- Fire and explosion
- Acute toxic hazards
- Occupational health hazards
- Environmental incident potential
- Transport incident potential
- Gaseous effluent
- Aqueous effluent
- Solid and liquid waste
- Energy consumption/global warming

At this stage the screening is likely to be carried-out by a small group of people from the project team.

It must be stressed here that although the techniques can ensure that issues are addressed and that rational decision making techniques are used, they can not provide a definitive 'Inherent SHE' solution. This is because the balancing of issues such as the safety of employees or the public against environmental protection, or even the relative importance of protecting the aqueous versus the atmospheric environment, involves value judgements which may vary from society to society as well as with time.

Similarly, no attempt has been made to balance Safety, Health and Environmental issues against cost. At the present time, there is no agreed basis for this and we believe that each company will need to develop its own approach to this matter.

6. TOOL TRIALS

A number of trials of the tools are currently underway and are of two types;

a) 'Desktop' trials in which an engineer or chemist uses the toolkit on a recently completed project to assess the viability of the technique.

b) 'Live' trials in which the toolkit is applied to a current project as the project proceeds.

Although the second type of trial is preferable, the very real problems involved such a need to raise awareness and educate the project team, possible impact on project programmes and selection of the appropriate stage in the project programme means that a mix of both types of trial has been necessary.

The trials have extended across a number of companies and project teams. To ensure consistency in the reporting of the results, on a standard questionnaire, was developed covering:

- how the toolkit was used
- effect on SHE performance
- effect on plant life cycle cost
- effect on operability/maintainability
- awareness of project design team

The trials (which are underway at the time of writing,) have covered both those projects where new process routes are being developed and those where an existing process is being modified or extended.

Full results of the trials will be available early in 1997.

7. CONCLUSION

Earlier work has shown that two of the main hurdles to the adoption of inherent SHE to be:

- The need for improved training
- A systematic method

A new training package has recently been made available and should fill the first need.

In addition, work by the industry / CEC co-sponsored project, has lead to the development of a toolkit which has been applied on a trial basis and will be made generally available during 1997. It is expected that the subject will remain high on the industry's agenda as attempts are made to meet ever higher safety, health and environmental targets in the most cost-effective way.

REFERENCES

1. Mansfield D and Cassidy K, Inherently Safer Approaches to Plant Design, Hazards XII, Manchester 1994, P285.

Figure 1

Application of Inherent SHE in Process Development

Stage I

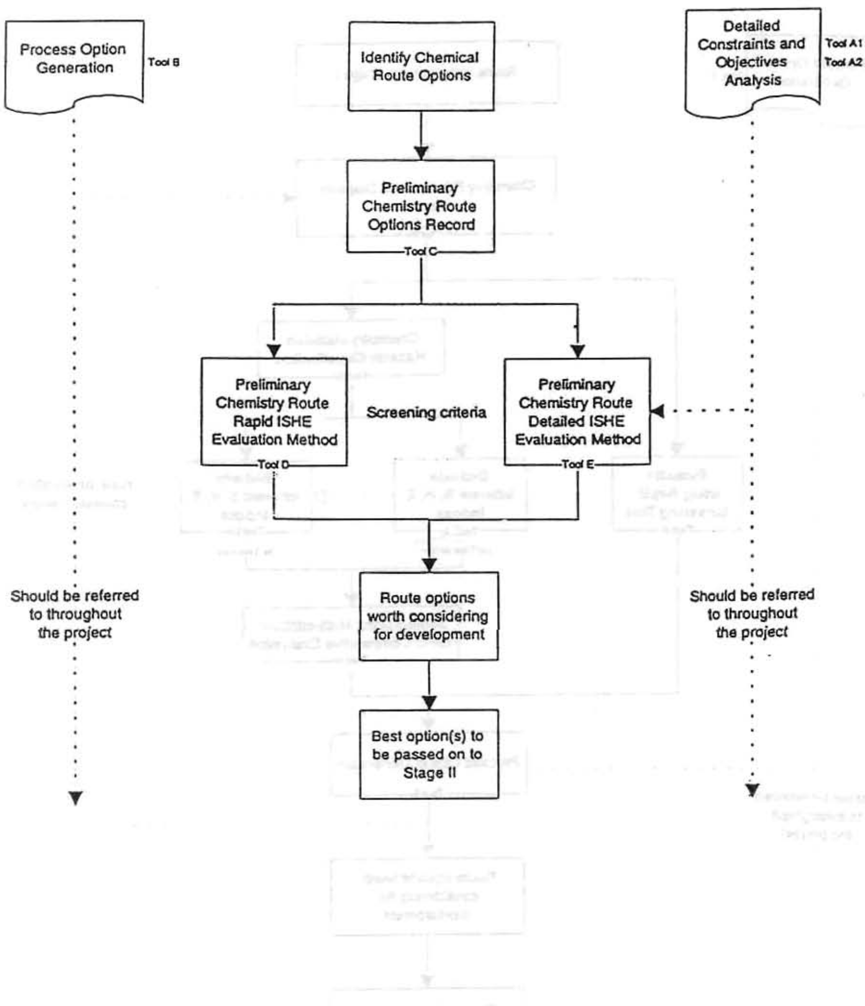

Figure 2

Application of Inherent SHE in Process Development

Stage II

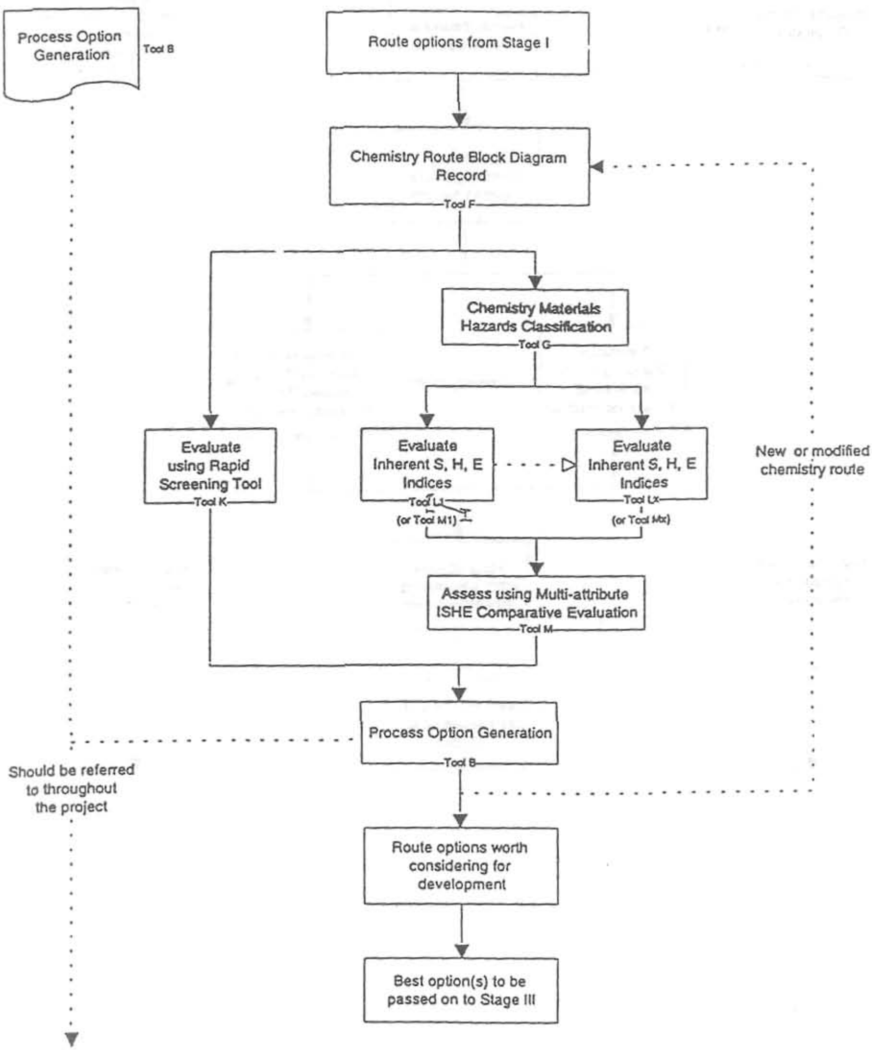

Figure 3

Application of Inherent SHE in Process Development

Stage III

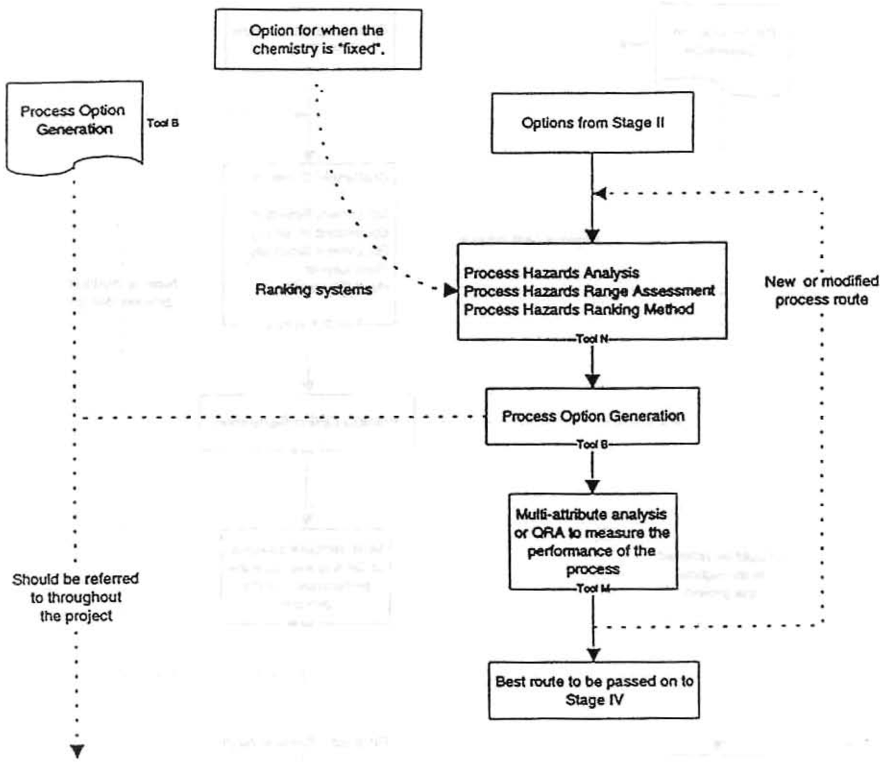

Figure 4

Application of Inherent SHE in Process Development

Stage IV